

## Possible Catalytic Effects of Ice Particles on the Production of NO<sub>x</sub> by Lightning Discharges

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One mechanism by which NO<sub>x</sub> is produced in the atmosphere is heating in lightning discharge channels. Since most viable proposed electrification mechanisms involve ice crystals, it is reasonable to assume that lightning discharge channels frequently pass through fields of ice particles of various kinds. We address the question of whether ice crystals may serve as catalysts for the production of NO<sub>x</sub> by lightning discharges. If so, and if the effect is large, it would need to be taken into account in estimates of global NO<sub>x</sub> production by lightning. In this study, we make a series of plausible assumptions about the temperature and concentration of reactant species in the environment of discharges and we postulate a mechanism by which ice crystals are able to adsorb nitrogen atoms. We then compare production rates between uncatalyzed and catalytic reactions at 2000 K, 3000 K, and 4000 K. Catalyzed NO production rates are greater at 2000 K, whereas uncatalyzed production occurs most rapidly at 4000 K.

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## The problem:

Ott et al. (2010) state that IC lightning and CG lightning produce equal amounts of NO<sub>x</sub>. Koshak et al. (2010) state that CG lightning produces more NO<sub>x</sub> than IC lightning.

Proposed solution: Ice crystals, only present in the upper sections of thunderstorm clouds, catalyze NO<sub>x</sub> production, making it appear that IC lightning's contribution rises to the level of CG lightning NO<sub>x</sub>.

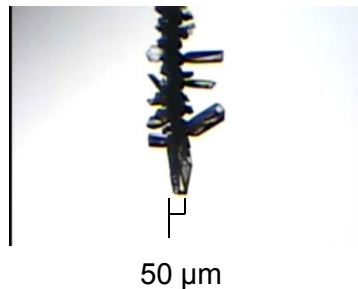
Proposed mechanism: Chemisorption of nitrogen atoms by water molecules on the surface of ice crystals

## Assumptions:

- Dendrites of mass  $10^{-8}$  g
- $10^5$  ice crystals/m<sup>3</sup>
- Nitrogen atoms produced in hot core (ice crystals destroyed here), chemisorbed in corona sheath

## Results:

- with hot core at 4000 K, uncatalyzed production rates; ice crystals consume N atoms
  - with hot core at 3000 K and below, catalyzed production rates are much higher than uncatalyzed production rates (an order of magnitude greater at 3000 K, several orders of magnitude more at 2000 K)
  - with a crystal density of 10 crystals/m<sup>3</sup>, uncatalyzed production rates are higher than catalyzed production rates due to the competing effect of lower temperature of N atoms bound to ice crystal surface
- The hot core spends more time at lower temperatures; therefore, overall catalyzed production will be greater than uncatalyzed production



Sample ice crystals, taken from Peterson et al. (2010)

Temperature	Uncatalyzed NO	Catalyzed NO
2000 K	Limited production	$3.77 \times 10^{-7}$ s
3000 K	$2.60 \times 10^{-6}$ s	$2.81 \times 10^{-7}$ s
4000 K	$1.49 \times 10^{-10}$ s	NO consumption

Table of preliminary results, detailing how quickly available nitrogen is converted to NO within the corona sheath. For the uncatalyzed reaction, little NO is produced at 4000 K as dissociation into N and O is favored, while little NO is produced at 2000 K due to unfavorability of oxygen atoms over oxygen molecules. For the catalyzed reaction, chemisorption of N onto the ice crystal surface shifts equilibrium away from NO production in the corona sheath when the hot core is at 4000 K.

## References:

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This research was supported by an appointment to the NASA Postdoctoral Program at the Marshall Space Flight Center, administered by Oak Ridge Associated Universities through a contract with NASA.